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UNDERGROUND WASTE DISPOSAL

AT

HANFORD WORKS

An Interim Report

Covering the 200 West Area

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ABSTRACT

A review of the past and present methods of underground disposal of liquid wastes at the Hanford Works is given.

A general picture of the geology of the region is presented with localized spots used for waste disposal being described in detail.

The results of the program in the 200-West Area indicate that the plutonium and fission products in the wastes are removed within a relatively short distance of the cribs; that the plutonium is removed from solutions closer to the cribs than the fission products; that the contamination so removed is largely deposited on the surfaces of the sand grains, from which it is not readily washed; and that the contamination is concentrated from the solutions on the grains. A total of 18,000,000 gallons of waste were discharged into these cribs and a few dry or reverse wells in the 200-West Area up to December 1, 1947.* This waste contained about 3,300 grams of plutonium and more than 50 curies of fission products, none of which is known or believed to have penetrated to the water table, from the disposal practices in the 200-West Area.

Results to date indicate that such disposal can be carried on over a long period of time. Observations over a period of several years are necessary, both in this and other areas, before final conclusions can be made however. Experiments in both the laboratory and in the field are continuing, which when completed will give a much more conclusive answer to the problem.

The description of the methods of drilling, sampling and analyzing the information are given.

6-15-48

* The abstract on Page 1 of Document HW-9671, dated May 3, 1948, entitled "Underground Waste Disposal at Hanford Works" by R. E. Brown and H. G. Ruppert is misleading in one respect.

It states that 3,300 grams of Plutonium were discharged to the ground in a total of 18,000,000 gallons of waste. This figure of 3,300 grams of Plutonium should be regarded from the point of view indicated in the last two paragraphs on Page 15 of the subject report. 19 rev

R. E. Brown
H. G. Ruppert

HEALTH INSTRUMENT DIVISION

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INTRODUCTION

Originally, it was planned to contain all highly active wastes in buried tanks taking all feasible precautions to inhibit tank failure and to dispose of the mildly active, so-called Class 4, wastes by seepage and evaporation on the ground surface. Dr. R. S. Stone, Dr. S. T. Cantril and H. M. Parker very early called attention to the hazard which might result from the drying up of such seepage areas leaving active material on the ground surface from which it might be widely spread by the wind. It was then decided to dispose of significantly active wastes in reverse or dry wells which had been provided for low level wastes. These wells varied in depth from 150 feet to 300 feet. The usefullness of these wells for handling large volumes of process wastes was questionable due to plugging of the wells with solids. In addition, it was realized that the injection points were,in some cases, within 100 feet of the ground water table and the radioactivity of the liquids was ten times as concentrated as originally estimated. The reverse wells are now regarded as a definite mistake and disposal into buried cribs has been substituted.

These cribs are approximately 12 feet square and 3-6 feet high and consist of a network of 6" x 6" timbers. The top and sides are then wrapped with heavy tar paper before burying at depths of 15 to 25 feet.

Laboratory investigation has confirmed the original hypothesis that the most dangerous element (Plutonium) was retained by the soil and has brightened the outlook for similar disposal of more active wastes. In the 200 Areas the peculiar geological conditions which support the crib method of disposal are 1) a general depth of 250 - 300 feet to the ground water table, 2) a thick series of unconsolidated river and shallow lake sediments,and, 3) a considerable distance from the point of disposal to points of use of the ground water or river water for domestic purposes.

In late 1946 a report was prepared to estimate the cost and feasibility of a well drilling program that would develop information on potential hazards originating from past and present methods of waste disposal to ground and from the proposed discharge of second cycle wastes to the ground.

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Consultive advice was solicited and received from the U. S. G. S. prior to the submission of the formal Project Proposal. After approval of the Project by the A. E. C., a geologist was added to the staff and the work has proceeded under his direction with consultatory help from the U. S. G. S.

The following report is the result of the first phase of the program to discover the long range feasibility of underground waste disposal. The report is limited to the 200-West Area because the drilling program was largely completed there except for a few current and future experiments. Future work in this and other areas will be described and discussed in later reports. The first phase of the drilling covered by this report was to determine what had happened to the wastes put into the ground. Future drilling is aimed at discovering the manner and means by which the wastes are dissipated within the sediments.

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PREVIOUS WORK

Published information on the underground waste disposal of liquids is very scanty, particularly in regard to the purification of industrial wastes by underground percolation. Purification of sewage, and purification of raw river water for domestic use by means of underground percolation have been successfully accomplished 1/ , but detailed information on the methods or means by which the purification was accomplished is not available. As late as 1947, O. E. Meinzer 2/ said:

> "A subject of great practical importance is the contamination of ground water with bacterial pollution and industrial wastes, and the capacity of the water-bearing materials to screen out or eliminate the bacteria and other objectionable substances. This is a borderline subject that has not received adequate systematic study by either the sanitary engineers or the ground-water hydrologists and on which coordinated effort is needed. Various methods for attacking these problems are available. Recently valuable results have been obtained in studies of wells that are supplied by water derived from nearby polluted streams, and these installations provide the means for further study".

Numerous reports have been written on the charging of the ground water system by the use of dams, ditches, basins, and shafts and wells, but few of these reports deal with anything but the quantitative effects on the ground water system. None were sufficiently detailed in regard to the manner, the speed or the means by which the water moved from the charging unit to the water table to be of value to the waste disposal problem at the Hanford Works. Moreover, the specific problem at the Hanford Works is not, primarily, of the movement of the waste liquids, but of the behavior of the radioactive suspensions and solutions within the liquids, and of their action on and within the sediments. The amount of waste liquid being discharged into the ground is quantitatively unimportant, and can have but little quantitative effect on the ground water system.

* * *

1. Scheelhaase, Dr., Producing Artificial Ground Water at Frankfort, Germany, Eng. News-Record, p. 174, July 31, 1924.

   Riedel, C. M., River Water Used at Dresden to Increase Ground-Water Supply, Eng. News, vol. 112, pp. 569-570, May 3, 1934.

2. Meinzer, O.E., Suggestions as to Future Research in Ground-Water Hydrology, Trans. Amer. Geophys. Union, vol. 28, no. 3, p. 420, June, 1947.

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Thus certain fundamental facts had to be determined, not the least of which was the detailed geologic picture of the subsurface conditions at the plant sites.

Previous geologic work in the area includes four published reports, of some value to the basic research involved in the study, but none of immediate and direct value. These reports are as follows:

1. Waring, Gerald A., Geology and water resources of a portion of south-central Washington: U.S. Geol. Survey Water Supply Paper 316, 1913.

2. Kocher, A.E. and Strahorn, A.T., Soil survey of Benton County, Washington: U. S. Bureau of Soils, 1919.

3. Jenkins, Olaf P., Underground water supply of the region about White Bluffs and Hanford: State of Wash., Dep't. of Conservation and Development, Div. of Geology, Bull. 26, 1922.

4. Culver, H.E., Abstract of the report (by Solon Shedd) on the geology and resources of the Pasco and Prosser quadrangles (Wash.): Washington Dep't. of Conservation, Div. Geology, Rep't. of Investigations, No. 1, 1926.

None of the above reports are the result of detailed field work, all are general in nature. Two early project reports were of considerable value in outlining the primary phases of the investigation to determine the feasibility of underground waste disposal. These are:

1. Gillson, J.L. (geologist, E.I.duPont de Nemours and Co.), Underground conditions at Hanford affecting disposal of industrial wastes: Hanford Works classified report, Project 9536, March 10, 1944.

2. Piper, A.M. (formerly district geologist, Ground Water division, U.S. Geological Survey), Disposal of wastes from the Hanford Engineer Works (Project 9536, Hanford, Washington: Hanford Works classified report, April 10,1944.

These two reports were used as a guide in the exploration work, and the recommendations in them were modified, amplified or discarded as work progressed and as detailed geologic information accumulated.

[redacted]

Numerous other geologic reports have been published on the general region or on minor features within the region, but these reports are either so general in scope or so limited in content as to be valueless to the immediate problem of waste disposal.

Object

Little published information is known to be available concerning the disposal of wastes underground, or the manner or means by which pollution or contamination is removed from liquids percolating or seeping through soil or sediments. Therefore a great deal of information had to be obtained, as outlined in the Introduction, and which is summarized below.

1. To determine what has happened to radioactive wastes already placed in the ground through reverse (dry) wells, subsurface cribs, and trenches.

2. To predict, on the basis of information obtained from Object 1, where the plutonium and fission products wastes will go that have already been discharged underground, and where any similar wastes will go that may be discharged into the ground in the future, in the 231 area, the 241-T area and the 361-T area.

3. To determine if higher activity wastes than have been discharged underground can be safely disposed of in a similar manner.

4. To determine if underground waste disposal is feasible over a long period of time, particularly in the areas under discussion.

5. To compare the relative efficiency of absorption of reverse (dry) wells, subsurface cribs and trenches.

6. To obtain all the geologic information possible, coincident with the drilling, so that as much might be known as possible about this not too-well studied area.

EQUIPMENT AND METHODS EMPLOYED

Drilling Machines and Equipment

Seven No. 70 Speed Star standard percussion well-drilling machines with the necessary operating tools were obtained. Each machine included a folding mast or derrick, a two-line hoist, one line for operating the drilling tools and the other for operating the bailer, a spudder for raising and dropping the tools, and an engine for power. Drilling consisted of alternately raising and dropping a heavy bit and drill stem to break the rock and loosen the material in the well. This loosened and broken rock, known as "drill cuttings", was then removed from the well with a standard dart bailer. All wells were cased, because practice showed that the unconsolidated sediments underlying the Hanford Works area would not stand long without support. Standard 8-inch casing was used, and was driven down the well as drilling progressed, by means of drive clamps fastened to the drill stem.

The maximum number of drilling machines in operation at any one time was six; the seventh rig was kept in standby condition.

Personnel

An operating crew of 16 men was required for the maximum of six operating drilling rigs; a driller and helper for each machine, two men to assist in moving the equipment and hauling supplies, a clerk, and an operating supervisor. The Health Instrument sampling crew consisted of one man for every two drilling rigs. Health Instrument supervision consisted of a supervisor and an engineer-geologist whose duty was to compile and correlate the information from the drilling logs, the samples, and the sample analyses.

Safety Precautions

Hard hats, leather gloves, and safety glasses were worn at all times during drilling. Special coveralls and rubbers were also worn in areas where a possibility existed of striking radioactive contamination in drilling.

Sludge boxes were also designed and built into which the drill cuttings and water were emptied from the bailer. The bailings were then water-jetted into a sump, 50 to 150 feet away. This procedure prevented the spread of radioactive contamination during drilling in contaminated zones, and also kept the drilling area clean and free from mud, itself a safety hazard.

The shoes and gloves of the operating crew were checked periodically with monitoring instruments, and the drill bit was carefully surveyed each time it was removed from the well. Similarly, the drill cuttings were checked with portable instruments before samples were taken. All outer surfaces of the equipment were surveyed for radioactive contamination on completion of drilling in one area, and the open ends of the sludge disposal pipe and the bailers were wrapped in paper.

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Drilling Plan for Each Site

A number of factors were considered in the planning of the drilling program at each site. The type of disposal unit, the location of underground pipe lines, and an estimate of the activity and the amount of solution discharged into the waste disposal unit were all considered. Three wells were then located about the waste disposal unit, equidistant from the unit and 120° apart. These initial wells were drilled to depths of 150 feet. Additional wells, located on the basis of information obtained from the first three wells, were then drilled to more accurately delimit the zone of radioactive contamination. These wells were generally drilled to a depth of ten feet below the zone of contamination. One well in each general area was also drilled into the zone of ground water, to obtain information on the type of sediments underlying the area to the water table, to permit sampling of the water for radioactive contamination and to obtain information about the ground water system. The pattern of drilling was governed by the consultative guidance of the Ground Water division of the U. S. Geological Survey, Portland Office.

Sampling Methods

Two one pint samples (original and duplicate) were taken at five-foot intervals from every well drilled. Similar samples were taken at one-foot intervals where contamination was suspected or known to exist. When the well was drilled to sampling depth, the bit was raised and held above the casing so that the water on the bit drained back into the well. The bit was carefully surveyed for contamination and then moved out of the way, and a bailer of drill cuttings obtained from the well. Two one-pint samples were taken from this material and placed in standard wide-mouthed glass, ointment-type jars, with screwtype lids. Part of one of the samples was then analyzed according to the field procedure outlined below. Labels were attached to the jars with the well number, depth of sample, date and time of sampling, and initials of person sampling. The well was carefully bailed dry, following sampling, if contamination was either suspected or known to exist, in order to prevent contamination of the samples lower in the well.

Sample Analysis

Field check: The field analysis was used to detect contamination in amounts requiring safety practices above and beyond the standard precautions in use in ordinary danger zones and as a rough check on the laboratory analyses. The levels of radioactivity used in the study of the contaminated zones were all obtained from careful laboratory analyses.

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The following equipment was used in the field analysis of the samples:

1. Geiger-Muller tube
2. Standard alpha counter
3. Infra-red ray lamp
4. Pan balance (0.1 gram sensitivity)
5. Stainless steel plates ($1\frac{1}{2}$-inch diameter)
6. Forceps and spatula

The procedure outlined below was followed in the field analysis of the samples:

1. Stainless steel plate was weighed
2. One to five grams of drill cuttings were placed on the plate and thoroughly dried under the infra-red ray lamp
3. A one-gram sample of the drill cuttings (dried) was selected, and the weight recorded.
4. The sample was counted in the standard alpha counter for one minute, and the result recorded in disintegrations per minute per gram.
5. Sample was counted on the Geiger-Muller tube for one minute and the beta-gamma count recorded as counts per minute per gram at reproducible geometry.

Drilling proceeded if the field check indicated less than 100 microcuries of fission products per kilogram of sample and less than 100 micrograms of plutonium per kilogram of sample. Drilling was stopped until additional safety precautions were taken if either analysis exceeded the above figures.

Laboratory Analysis

A more sensitive and accurate analysis of the radioactivity of the drill cuttings was made in a chemical laboratory. This analysis was similar to that of the field check, except that the samples were counted using a mica-window tube on the beta-gamma counter. This type of instrument has a geometry of approximately 13 percent, instead of the one percent of the instrument used in the field check. The plutonium analysis was made by chemically extracting the plutonium from a 10-gram sample of drill cuttings and counting the resulting concentrate in a standard alpha counter.

Sample Storage

All samples were taken from the laboratory and field to a central storage building. The sample jars were cleaned, relabeled, and the labels protected with clear lacquer. The jars were then stored on shelves so designed that all samples are easily accessible and visible. Samples contaminated with fission products were marked with a strip of blue Scotch tape; those with plutonium contamination were marked with a strip of red.

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Some trouble was experienced in the storage of the samples, in that those samples containing clay or silt developed considerable growths of several kinds of algae. This could have been prevented by drying the samples at the time they were taken, but such a practice would have been hazardous in view of the plutonium and fission products contamination present in some of the samples. Accordingly, all samples were stored wet. Those samples that developed algal growths, and which laboratory analysis indicated as free from radioactive contamination, were air dried, in which the jars were opened on the storage shelves. Care was taken that air currents did not materially disturb and carry away the algae as it dried.

Compilation and Correlation of Information

The method of defining the limits of contamination around the waste disposal units follows closely the method used in defining the ore bodies in mining areas, and in the compilation and correlation of information about them. Each sample was carefully examined megascopically, described with all data that might be pertinent, and plotted on a graphic log. The geologic log was then compared to the drilling log and additional pertinent information added. Stratigraphic and lithologic correlations were made between wells, after which numerous, accurate geologic cross sections were drawn through the crib areas. The contamination was then plotted as to type, location, and intensity in each well, so that an accurate correlation could be made between the type and attitude of the sediment and the extent and intensity of the plutonium and fission products contamination. Assay sections, plans, and contamination intensity curves were also constructed, and contamination contours (isodoses) were located and drawn. (see plates 2, 5, 6, 8.) The decrease in intensity of contamination both downward and outward from the cribs was thus determined and the probable limits of contamination determined by projection of the curves of intensity correlated with the shape of the contamination zone. Holes drilled on the basis of such projection in the 361-T area demonstrated the applicability of the method for both the plutonium and fission products contamination, and showed that both the thickness and intensity of the contamination can be roughly predicted. However, the contamination picture is obviously correct only at the time of drilling, and migration of the contamination is not only possible but probable, even though no additional wastes may be jetted into the crib. Such migration is believed to be small in amount, but careful observation for at least a year, in addition to numerous laboratory experiments, may be necessary to determine how well fixed the contamination is and how much migration may be expected in the future.

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PROGRESS

Drilling in the 200-West Area began with the 231 Area. The first well was started March 25, 1947. On October 24, 1947 the last well in the 241-T Area was completed, thus completing the planned program in the 200-West Area. During this period, a total of 47 wells were drilled, as follows:

Area	Wells	Total Depth in Feet	No. Samples
231			
No. 1 crib	8	1291	270
Well 231-W-150	3	525	210
231 Total	11	1816	480
361-T	13	1495	656
241-T			
224-T (201 tank crib)	8	1055	386
2nd cycle crib	15	2095	482
	47	6461	2004

In addition, three wells, each 150 feet deep, were drilled adjacent to the 231 waste disposal trenches. These wells, although not on projects C-120 or C-133, added to the information obtained from those projects, and demonstrated that contamination to date was not spreading north of the trenches toward the 241-TX tank farm.

Standard operating procedure had to be revised only once, in well 361-T-6. Both the fission product and plutonium contamination exceeded the safe operating limits of 100 microcuries per kilogram of sediment and 100 micrograms per kilogram of sediment respectively, so that a revised method of sample taking became necessary. The bit and bailer, when withdrawn from the well, were held over the casing and allowed to drain back into the well during the time necessary to survey them for contamination. Then, when either was moved away from the casing, a bucket was held beneath them to catch any water that might drip and that might be contaminated. Much greater care was also exercised in the taking of the samples. Individual cardboard funnels were used with each sample to fill the jars and were then discarded in a contaminated waste carton. The well was carefully bailed dry between sampling and drilling, in order to prevent the downward spread of contamination during drilling. The water level in the well during drilling was also maintained at a depth of 5 or 6 feet, instead of 10 or more, so that the bailer would fill only

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about half full of water during bailing operations. Splashing of contaminated water from the top of the bailer was thereby eliminated.

The bit and bailer used in well 361-T-6 were found to be highly contaminated during and as the result of drilling in the highly contaminated zone, but during the drilling into the less contaminated sediments the contamination was worn off. No contamination was detected on either bit or bailer by the use of standard instruments by the time the well was completed.

The operating procedures outlined above and in the preceding sections proved adequate and satisfactory in nearly all respects. The program was completed with no significant radiation exposure to personnel, and with no detectable spread of contamination.

SUMMARY OF RESULTS

Spread and Intensity of Contamination

The results of the use of the waste disposal units are summarized on the accompanying plates and in Table 1. The plutonium was generally sorbed (absorbed and/or adsorbed) by the sediments and removed from the solutions within a short distance of the crib, in contrast to the fission products, and in no case was found at a depth greater than 34 feet below the bottom of the crib. Its lateral movement was also less than that of the fission products in any one area drilled, and was generally more predictable and regular in extent. This greater irregularity in the fission products contamination is probably due at least in part to the large number of radioactive elements present in the fission products waste liquids. Some of the radioactive elements are undoubtedly removed from the solutions and suspensions with the plutonium, but others probably remain in solution for a much longer time and are removed from the liquids only at greater depth and distance from the crib, owing to reasons as yet only partly understood. Laboratory determinations are being made of the specific fission products present at different depths in the 361-T area contamination zone to confirm this idea. If such a natural separation is clearly confirmed and defined, the extent of the zone of fission products ground contamination can be limited in future waste disposal areas by plant separation and removal of those fission products remaining in solution for the longest time and migrating the greatest distance from the waste disposal unit. Thus, areas believed to be not suitable for underground waste disposal could conceivably be made suitable by changing the character of the waste solutions.

The results of the deposition of the contamination are summarized as follows:

Area	Plutonium contamination		Fission products contamination	
	Depth Below Crib	Lateral Spread	Depth Below Crib	Lateral Spread
231	32 feet	103 feet	None present	
361-T	20 feet	45 feet	107 feet	95 feet
241-T (224-T or 201-tank crib)	34 feet	197 feet	28 feet	280 feet

This more restricted movement of the plutonium is extremely significant, for it strongly suggests that the plutonium will be removed from the waste solutions well above the water table. The fission products, although they may migrate to the water table in some instances, create a far less serious problem, for not only are they less dangerous, but because some of them have relatively short half lives, the total activity of the fission products in the ground water will be greatly reduced by the time the ground water has moved to areas where it may be used by living organisms.

Table I indicates in a general way the effectiveness of the sediments in removing contamination from the waste solutions and suspensions. The total amount of plutonium and fission products in the ground was calculated, using the sample assays, plan maps, cross sections, contamination curves and contamination contour (isodose) maps and sections. The method used was identical to that used in the determination of the grade and volume of an ore body in a mine. In Table I, the amount of radioactive material discharged into the crib or other unit as calculated from the assays and maps and sections is referred to as the "calculated" radioactivity. The amount of radioactivity discharged, on the basis of tank analysis and amount of liquid jetted, is referred to as the "recorded" radioactivity.

A few facts are well demonstrated by the Table I. The amounts of plutonium and fission products in the ground, as calculated from the assays, plan maps, sections, and contamination contour maps were generally considerably below the amounts recorded as discharged into the units. The contamination zones were believed to be well delimiated in every case, at least to a degree well within the difference in the calculated and recorded amounts of plutonium and fission products within the ground. An analysis of the apparent reasons for the discrepancies is of interest.

TABLE I

Summary Figures, 200-West Area Waste Disposal Units

December 1, 1947

Unit	Size	Total Volume Waste in Gals.	Rate in gal/min.	Recorded radio-activity (Amts. Approx.)	Calculated Radioactivity	Calc./recorded Radioactivity	In Use
231-W-150 (reverse well)	6", 150' deep	260,000	20	100 g. Pu	None found at 15 ft. radius	------	No, sealed with sludge
231-W #1 and 2 cribs (See page 15)	12'x12'x4'	7,100,000	100	3000 g. Pu	0.5 g. Pu	1/6000	No, sealed with sludge
231-W trench	150'x8'x2'	2,500,000	100	10 g. Pu	None found at 60-ft. distance	-----	Yes
241-T #1 & 2 cribs (201-T Tank Cribs)	12'x12'x4'	1,200,000	100	20 g. Pu 3 c. F.P.	7 g. Pu 2 c. F.P.	7/20 2/3	Yes
241-T #3 crib (2nd cycle)	12'x12'x4'	500,000	100	2 g. Pu 3 c. F.P.	None found in #1 Well 20 ft. beneath crib	----- -----	Yes, waiting on casing sampler
241-T-361 A (reverse well)	8", 206' deep	3,000,000	100	100 g. Pu. 25 +c.F.P.	area not drilled	----- -----	No, sludge in tank
361-T #1 & 2 Cribs	12'x12'x4'	2,300,000	100	150 g. Pu ---- c. F.P.	25 g. Pu 21 c. F.P.	1/6 -----	Yes
		18,000,000 gallons		3400 grams Plutonium 50 curies fission products			

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HW 9677

231-Area

No plutonium was found in any of the samples from the three wells drilled in the 231-W-150 reverse well area. These three wells were drilled to depths of 175 feet, 25 feet below the bottom of the reverse well, and only 15 feet from the reverse well. Contamination may have channelled out laterally from the well and not been detected by any of the three test wells, but the rate of discharge (20 gallons/minute) was so low that all the liquid could have moved downward and never reached the area drilled. Moreover, the relatively small amount of waste liquids discharged into the well (260,000 gallons) before the well was sealed suggests that contamination may be confined within the 30-foot diameter circle formed by the three wells. Other waste disposal units which have absorbed far greater amounts of wastes than the 231-W-150 well have created zones of plutonium contamination of far smaller diameter for the quantity of wastes discharged than the 30-foot diameter circle around the 231-W-150 well. Thus, on the basis of comparison with other units, the contaminated zone at 231-W-150 lies within the 3 wells drilled, and need not go to considerable depth. The well stratified Ringold (?) formation into which the reverse well penetrates should certainly cause the waste solutions to spread laterally rather than vertically. The clay and silt bed which here forms the topmost member of the formation undoubtedly retarded the movement of the solutions and probably sorbed much of the contamination. The clay and silt probably aided in sealing the well, by being washed into the casing during discharge of the wastes into the well.

It should be noted here that Table I indicates that the total quantity of Plutonium discharged from the 231 Building to the 231 #1 Crib was approximately 3000 grams. This figure is in actuality probably high by a factor of 10 to 50. The reason for the existence of the apparent discrepancy is that the minimum concentration of plutonium in the waste solutions reported by the process control laboratory during the period that the #1 Crib was used was 0.1 mg/liter.

The 3000 gram figure was obtained by assuming that all wastes reported as containing not more than 0.1 mg/liter actually did contain as much as 0.1 mg/liter. Subsequent analyses on process wastes indicate that the average plutonium content in these discharged wastes was actually between 2×10^{-3} mg/liter and 10^{-2} mg/liter. Because the 3000 gram figure was used, the ratio of the calculated activity and the recorded activity is 1/6000, whereas the real ratio may easily be as good as 1/200

Only about half a gram of plutonium was accounted for in the 231 No. 1 crib area, although nearly 3,000 grams were discharged from the 231 Building. The drilling program is believed to have thoroughly delimited the contaminated zone both laterally and vertically; therefore the remainder of the plutonium must be either in or directly beneath the crib in an area untouched by drilling. Inasmuch as the crib was abandoned because it was sealed with sludge, these conclusions are probably correct. No contamination was noted in the three wells drilled adjacent to the present cribs (trenches), although the distance of 60 feet is apparently too great for the contamination to have migrated in the 10-month period that the crib was in use prior to the drilling. Moreover, the contamination, as suggested by the 241-T area, the 361-T area, and the 231 No. 1 crib area, probably moved to the south, southeast or east, away from these three wells (241-TX group).

361-T Area

The 361-T area zone of contamination is similar in many respects to that of the 231 area. A more detailed program of drilling adjacent to the crib resulted in a more detailed picture of the zones of contamination and in a clearer picture of the gross controls apparently governing the removal of the radioactive elements from the waste solutions. The calculated amounts of plutonium and fission products also more nearly approached the recorded amounts discharged into the crib. This is partly due to the closer drilling pattern and consequently more accurate determination of the amounts of contamination present, but probably also to the fact that the crib is still in use and is not sealed with radioactive sludge.

The 241-T-361 A reverse well area was not drilled. Well 241-T-361, drilled to a depth of 287 feet, struck water at a depth of 285 feet and was therefore never used for a waste disposal unit. Well 241-T-361 A was then drilled 27 feet away to a depth of 206.5 feet and was used for waste disposal as indicated on the accompanying table. The immediate area was not drilled because of the considerable depth to the zone of contamination, the fact that nearly 80 feet of Ringold (?) sediments lies between the bottom of well 241-T-361 A and the water table, the fact that plutonium migrated downward only 20 feet in the 361-T tank crib area and should do likewise in the 241-T-361 A area, and the fact that water samples from well 241-T-361 should indicate whether or not the ground water has been contaminated. To date no samples have been taken from this well.

241-T Area

The 241-T area (201-T tank crib) contamination zone is characterized by a large lateral, but small vertical, extent as shown on the contamination diagrams. The calculated radioactivity rather closely approached the recorded radioactivity for both plutonium and fission products, which together with the large lateral spread for a rather small amount of waste solution (1,200,000 gallons) as contrasted to the 7,000,000 gallons discharged into the 231 crib indicates that little plutonium and fission products are concentrated in and beneath the crib.

The large lateral but small vertical extent of the contamination contrasts strikingly with the extent of the contamination in the other areas drilled. No clay beds or zones were noted at or close beneath the zone of contamination, neither was any change in the grain size or in the degree of sorting noted that should change the permeability of the sediments. Thus the reason for the spread appears to be due to other factors.

Careful examination of the drilling logs of the 224 T and the 241-T wells discloses that in almost every case where the records were complete, the wells lost water during drilling to a depth at which the contamination appeared. From that depth downward to the bottom of the wells, the water remained in the wells. Wells outside the contaminated zones behaved similarly at corresponding depths. Thus the sediments at that depth had a permeability less than that of the sediments overlying them, yet no significant change was noted in the samples.

A comparison between the 231, 241-T and 361-T areas develops several facts of significance. (see plate 1) The direction of contamination spread in all three locations is between south and west. The upper surface of the clay bed, indicated as the uppermost bed of the Ringold (?) formation, strikes about N. 31° W. and dips about 1° SW, as calculated from the depths to the bed in all three areas drilled. This attitude is corroborated by a fourth point, a refraction seismic line shot by the U. S. Army Corps of Engineers, which indicated Ringold sediments at an altitude of 516 feet, at a point at N. 34,400 and W. 62,300. This is further corroborated by Durand Well 13/25 33 D1, location about N. 48,800 and W. 95,000, which reputedly encountered Ringold sediments at an altitude of 714 feet. If we calculate the altitude of the formation from the seismic line information, the Durand well, and from the 241-T, 361-T and 231 area wells, we obtain a strike of N. 65° E. and a dip of 1° SE.

The elevation of the water table in all three areas drilled discloses that its gradient is about 1 foot in 100 feet in a direction S. 54° E. This gradient is considerably greater than that in the 200-East area, where it approximates 1 foot in 1,000 feet. This is due to three factors: (1) the ground water in the 200-West area is entirely in the Ringold (?) formation, whose sediments are of lower permeability than the sediments of the recent alluvium. Thus a steeper water table gradient may be expected. (2) The 200-West area is near the Rattlesnake and Yakima Ranges, which supply considerable ground water to the area. Thus the water table gradient will steepen in that direction. (3) Up to 2,000 gallons a minute (1,000,000 to 1,500,000 gallons per day) of effluent and sanitary (non-radioactive) water are discharged on the ground and allowed to percolate into the sediments only a short distance north of the 241-T area. (see plate 1). This is the equivalent of about 4 acre feet of water per day, which, if we assume the average porosity of the sediments is 20 percent, will saturate one acre of sand and gravel to a depth of 20 feet, and will raise the water table by an amount determined by the rate at which the water can move downward to the water table and outward from the discharge area. This local raising of the water table is suggested by Durand well 13/25 33D1, which reputedly encountered water at an altitude of 410 feet, lower than that of the water table in well 224-T-4 of 440 feet.

The direction of dip of the Ringold formation and the direction of spread of the contamination thus indicate that any water added to the sediments above the water table will move southward as it moves downward. Thus, the effluent and sanitary water poured on the ground north of the 241-T area probably moves largely to the south, down the dip of the upper surface of the Ringold (?) formation before it penetrates to the water table. If the water remains above the clay bed, it will pass beneath the 241-T area and either saturate or thoroughly moisten the sediments, in either case forming a wetted zone that would tend to support the liquids penetrating downward from the 201-tank crib. Thus the contamination would be confined to a narrow vertical zone at or near the top of the wetted zone, but would be spread laterally for some distance.

Total Quantity of Wastes Discharged

A total of nearly 18,000,000 gallons of radioactive waste has thus been discharged into the sediments underlying the 200-West area, up to December 1, 1947. This waste contained a recorded amount of about 3,400 grams of plutonium and 50 curies of fission products, none of which is known or believed to have penetrated to the water table. Thus the monetary saving of this method of waste disposal over that of tank storage is considerable. Moreover, barring unforseen conditions, the contamination is safely bound with the sediments in a state where it can cause little danger in the future.

Controls Contributing to Removal of Radioactive Contamination from Waste Solutions

A number of factors are of significance in removing radioactive contamination from the waste solutions. The gross controls are well demonstrated on the cross sections accompanying this report. The permeability of the sediments is of paramount importance in obtaining a flow of liquid away from the waste disposal unit, but high permeability is itself detrimental to the confinement of the radioactivity. The ideal conditions are apparently a series of flat, or nearly flat-lying sediments of varying permeability, so that the waste solutions, although moving downward, are also spread laterally. The zones of contamination are thus easier to explore by drilling, and a more positive check is had of the extent and intensity of the contamination, and of its movement.

The 200-West area is quite ideal for underground waste disposal. The recent alluvium is generally well stratified, and consists of alternating layers of sand and gravel of varying permeability. Beneath the alluvium is the Ringold (?) formation at a depth of about 110 feet, topped by a bed of pale buff-colored, nearly impermeable, fine-grained sand, silt and clay, from 20 to 50 feet thick. This particular clay bed was recognized beneath the 231 area, the 361-T area, and the 241-T area and is presumably continuous throughout the entire 200-West area. It therefore creates the optimum conditions for localization of the contamination above the water table.

Probably also important is the belief that the waste liquids must not move too rapidly, although what speed this is is not known. The best results to date have been obtained with fine - to medium-grained sands (from 1/8 to 1/2 mm. in diameter), although results are far from conclusive as yet. Sands of this grain size, if clean, are quite permeable, yet the pore spaces are small enough so that the waste liquids, and the radioactive products, are constantly close to the surfaces of the sand grains.

A sample of the highly contaminated sand from the 22-foot level of well 361-T-6 was size sorted into five size fractions, in order to test the change in amount of contamination with change in grain size. The sizes separated were as follows:

1. Passed by 32 mesh
2. Passed by 32 mesh, retained by 100 mesh
3. Passed by 100 mesh, retained by 150 mesh
4. Passed by 150 mesh, but can be centrifuged
5. Cannot be centrifuged

Analyses were made of all size fractions for both plutonium and fission products. The results clearly demonstrated that the amount of contamination was directly dependent on the surface area of the grains, and therefore on the size of the grains. The fission products, at least, to a certain extent, undoubtedly also enter into the crystal structure of the clay minerals. The test described above was, however, far too incomplete to detect any increase in the radioactivity of the clays above the theoretical figure based on surface deposition only. Therefore, the smaller the grain size, the greater will be the total surface area exposed to the solutions, and the more effective will be the removal of the contamination.

[redacted]

[redacted]

The contamination is apparently well fixed on the surfaces of the sand and is not easily removed by ordinary water. A soil column test was made to test this possibility, in which radioactive solutions, containing approximately the radioactivity of the waste solutions, were passed through a column of sample material. The radioactivity was removed from the solution by the material, and when pure water was poured through the column the amount of contamination removed was negligible.

Higher activity wastes can apparently be safely discharged into the ground. A few figures can be cited, showing the relative concentrating effect by the sand on the radioactive contamination.

361-T tank analysis	Sample analysis, well 361-T-6 depth 22 feet
Alpha 8.7×10^{-7} curies Pu/liter	560 microgams Pu/ kilogram
Beta 2.5×10^{-6} curies/ liter	
Gamma 6.1×10^{-8} curies/ liter	100 microcuries/ kilogram

If we assume that the contamination is removed from the solution and deposited on the sand grains purely as a surface phenomenon, then three liters of sand, with an average porosity of 30 - 35 percent (average for this type of sand) will be able to contain one liter of water. The specific gravity of the sand is about 2.9, so that three kilograms of sand will be contained in one liter of sand. Therefore 9 kilograms of sand will be able to contain the one liter of water. The concentration factor is thus as follows:

560 micrograms Pu/ kg. = 5040 micrograms Pu/ 9 kg. = 315×10^{-6} curies Pu
100 microcuries FP/kg. = 900 microcuries FP/ 9 kg. = 900×10^{-6} curies F.P.

And: $315 \times 10^{-6} : 8.7 \times 10^{-7} = 362 : 1$

Therefore the highest contamination of the sand encountered in the 361-T area represents a concentration of 362 : 1 over the contamination of the original solution, for plutonium.

Similarly:

$900 \times 10^{-6} : 25.61 \times 10^{-7} = 351 : 1$ (beta plus gamma)

The highest concentration of fission products in the sand from the 361-T area is therefore 351: 1 over the contamination of the original solution.

By similar means, the concentration in the 224-T (201-T tank) crib area was determined to be 10:1 for plutonium, and 14:1 for the fission products (beta plus gamma). For the 231 area, the concentration factor was negative, that is the plutonium in the highest contaminated sample encountered was 1/10 the concentration of the plutonium in the original waste solution.

[redacted]

The above calculations are extremely rough. The concentration is apparently dependent on the surface area exposed to the solutions, and therefore on the grain size, whereas the above calculations are based on a volume relationship between the contamination in the waste liquid, and the volume of sand necessary to contain that amount of waste liquid. The concentration factor in the 361-T area clearly indicates that higher activity wastes can be discharged into the ground under the right conditions. Many laboratory experiments must be made, however, before definite conclusions can be reached as to the degree of higher activity that can be discharged into the ground, or the rate at which such discharge can be made.

Underground waste disposal in the 200-West area has been successful to date. Indications are that it will be feasible for a considerable period of time because not only is the contamination removed and concentrated from the waste solutions, thereby removing the necessity for storing the water, but because the waste is concentrated in areas where it can be periodically checked and observed. Only observations over a period of several years can positively determine the effectiveness of underground waste disposal. Present conclusions strongly recommend further investigation into the possibility and feasibility of underground waste disposal in this and other areas, and the means for further improving the present system of disposal. Many laboratory tests will have to be made to determine the degree of fixation of the radioactive materials on the different types of sediments, the maximum concentration that can be built up on the grains, and the effectiveness of clay and silt in adsorbing and absorbing the contamination. As many as 5 or 6 factors may control the removal of the radioactive materials from the waste liquids, and the absence of any one of these may easily prevent such removal. Further work, both in the laboratory and in the field is certainly vital.

Table I also gives a rough indication of the effectiveness of dry (or reverse) wells, cribs and trenches. Well 231-W-150 plugged after only 260,000 gallons of waste had been discharged into it, whereas the No. 1 crib absorbed 7,100,000 gallons. The present 231 cribs (trenches) will presumably absorb considerably greater amounts than the crib. Other comparisons can not be made because all other waste disposal units are still in service. The effectiveness of a unit, and the rate at which it will absorb waste liquids are obviously directly related to the area of sediments directly exposed to the waste liquids, through which the liquids can percolate. For that reason the larger the area, the greater the effectiveness. Wells are generally not satisfactory for other than small amounts of waste for the following reasons: 1. They must be deep to be able to contain even a moderate amount of liquid, and therefore must penetrate much closer to the water table than shallow, but larger, cribs. 2. Wells perforated over a considerable depth will be subject to the washing in of sand, silt and clay which will rapidly reduce the effectiveness of the unit. 3. The area of sediments exposed to the solutions is extremely small compared to the area exposed in a crib. 4. Contamination is much harder to trace and delimit in a deep well area than in a shallow crib area.

CONCLUSIONS

Results obtained from the drilling program to date have far exceeded expectations. The method of drilling has proved adequate and satisfactory, the information obtained has demonstrated that underground waste disposal is feasible, and the conclusions reached have encouraged the further expansion and development of the program.

FUTURE DEVELOPMENT

Future development of the waste disposal program rests on two main problems. The first of these is the behavior of the waste products underground as they are discharged into the ground, and their behavior with the passage of time. The pictures obtained to date are static, that is were obtained at a specific time and do not show the changes that probably will occur, even without the discharge of more wastes. The wells drilled in the 241-T 2nd cycle crib and tile field area were drilled prior to the construction of the crib and tile field. These wells will be sampled periodically during the use of the crib with the casing sampler recently designed and built. This sampler will obtain samples of the sediments through the well casing and will permit determination of the changing radioactivity of the sediments as the crib is used.

The second problem is to determine the depth to and the direction of movement of the ground water throughout the area immediately surrounding the 200-West area, as part of the general ground water and geologic studies of the entire Hanford Works region. Several wells will be drilled to the north, to the west, and to the south of the area, to expand the geologic and ground water information already obtained in the 200-West area. Some of these wells will be drilled to further explore the effect of the effluent water spreading on the ground water table, and to explore the possibility of discharging the effluent and sanitary water at a point several miles from the area to eliminate interference with the underground waste disposal in the 200-W area.

Drilling at the present time is being concentrated in the 200-East area, where problems both similar to and unlike those in the 200-West area have been encountered. The description of these problems, and the results obtained from the investigation and drilling will be described in a later report, on completion of the work in that area. Experiments to determine the effectiveness of the sediments in removing the radioactivity from the waste solutions are also being carried on in conjunction with the drilling program.

[redacted] DECLASSIFIED HW-9671 P.27 PLATE 1

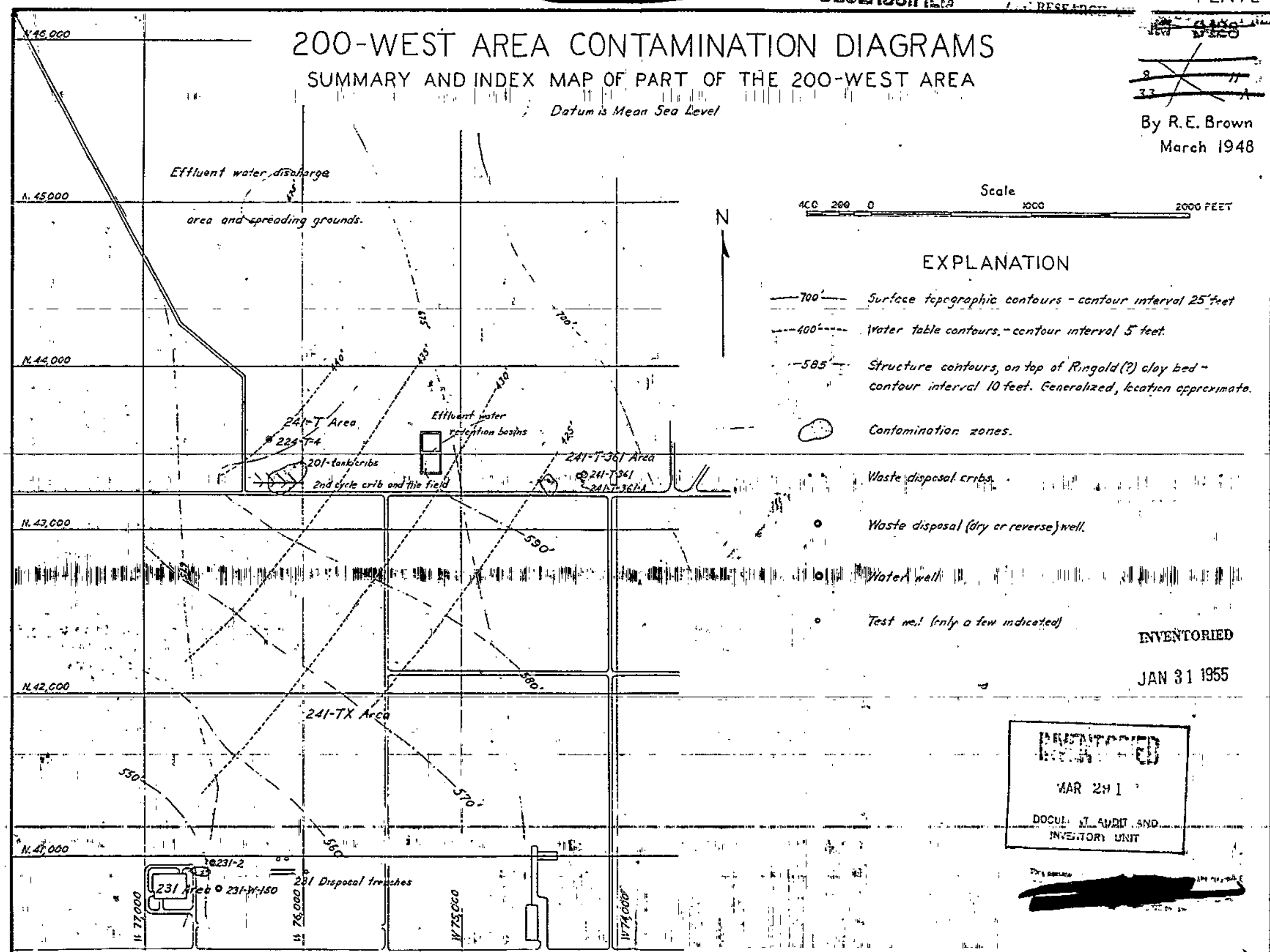

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PLATE 2

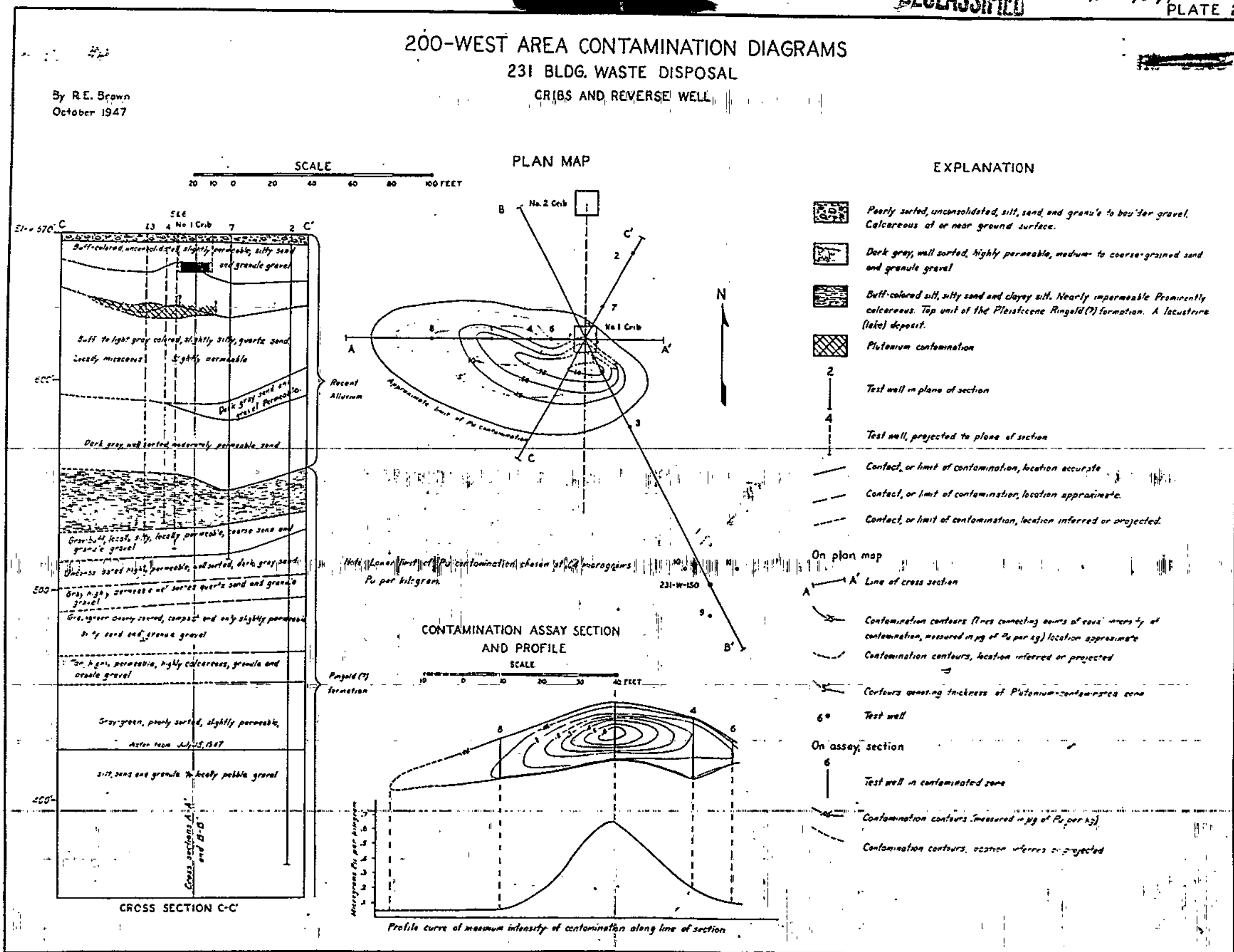

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PLATE 3

200-WEST AREA CONTAMINATION DIAGRAMS

231 BLDG. WASTE DISPOSAL

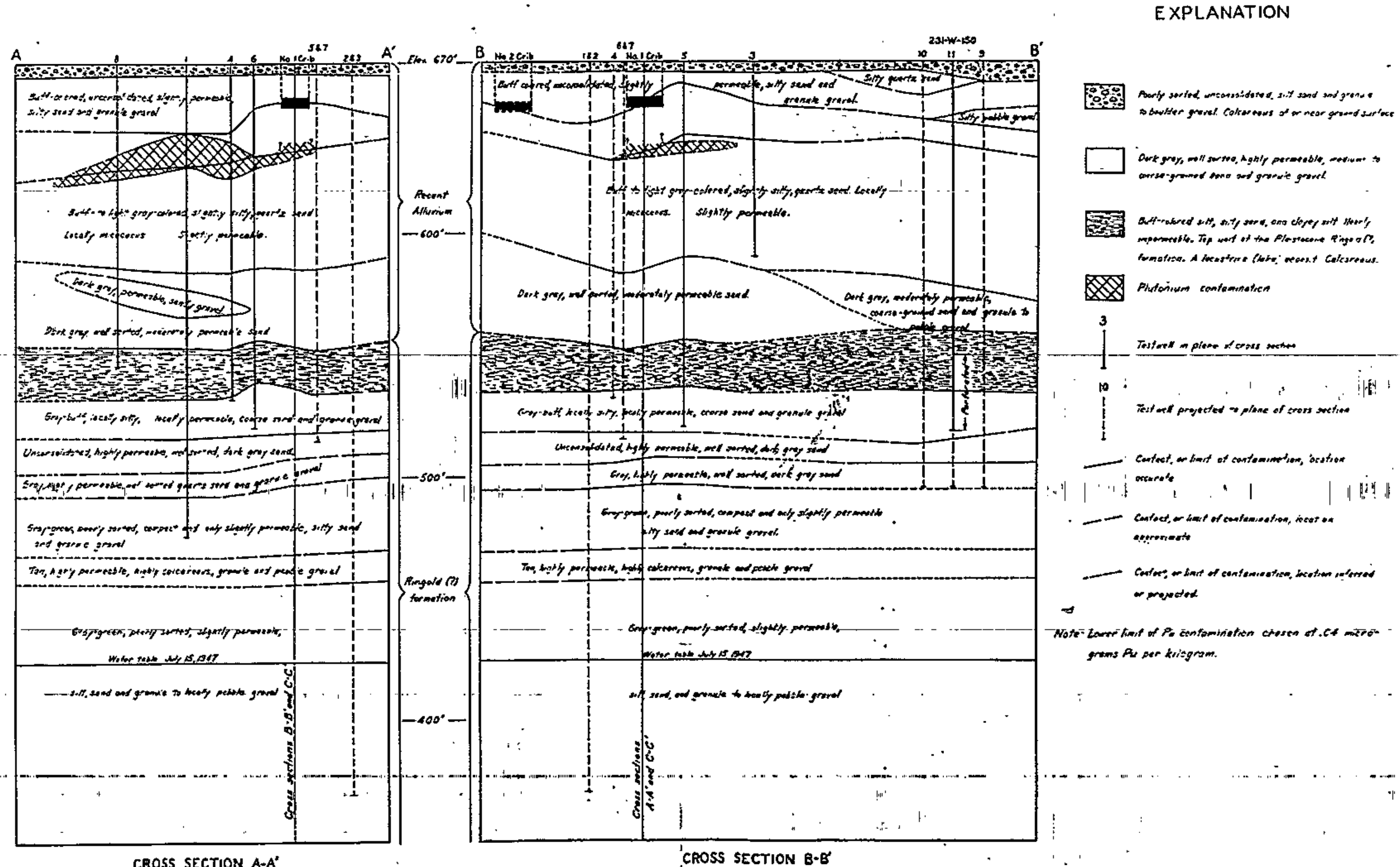
CRIBS AND REVERSE WELL

By R.E. Brown
October 1947

SCALE

20 10 0 20 40 60 80 100 FEET

Datum is mean sea level



CROSS SECTION A-A'

CROSS SECTION B-B'

DECLASSIFIED [redacted]

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HW-9671 PLATE 4 P.30

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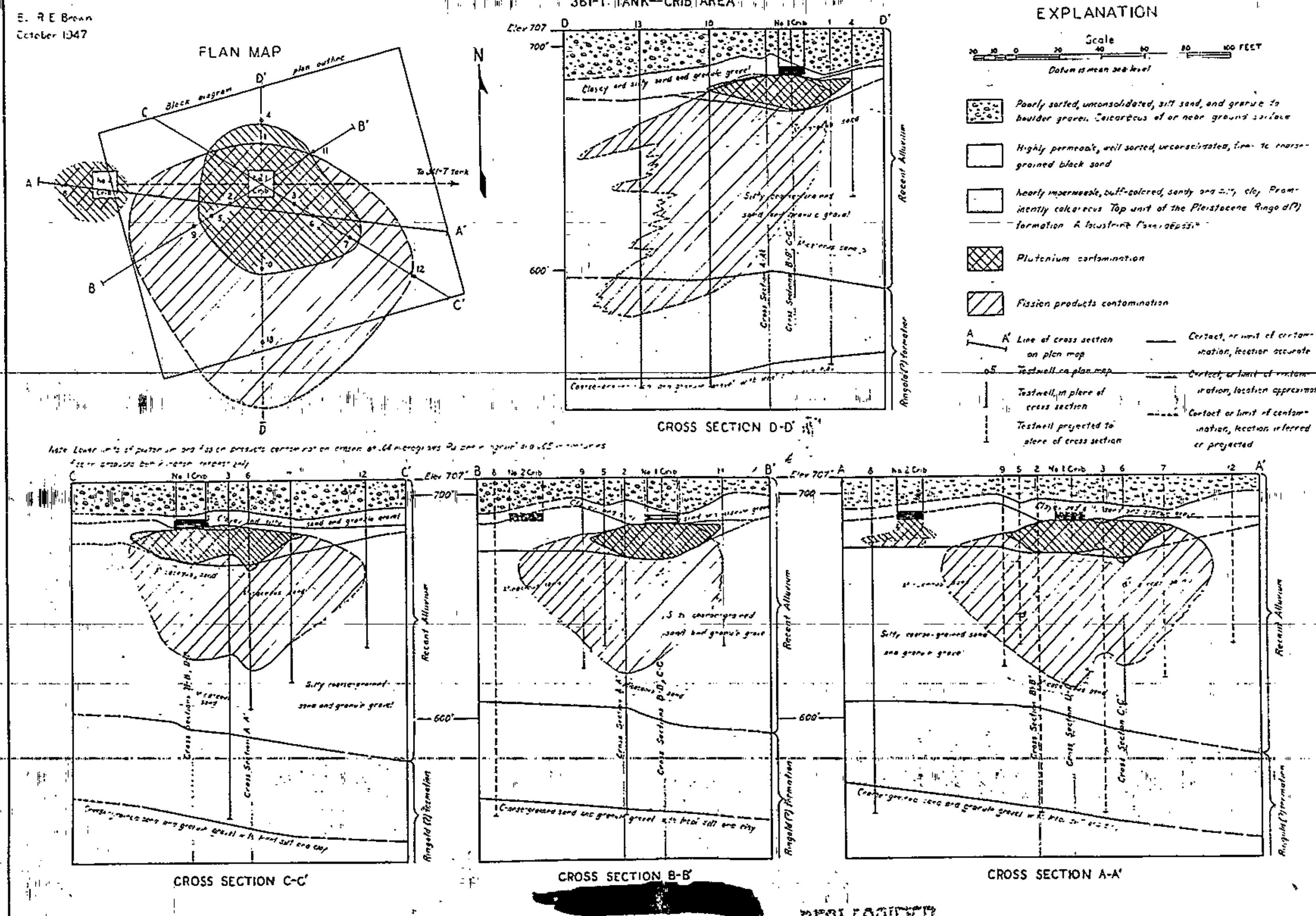
200-WEST AREA CONTAMINATION DIAGRAMS

224-T BLDG. WASTE DISPOSAL

361-T TANK—CRIB AREA

E. R. E. Brown
October 1947



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[redacted] DECLASSIFIED HW-9671 p.31
PLATE 5

[redacted]

200-WEST AREA CONTAMINATION DIAGRAMS

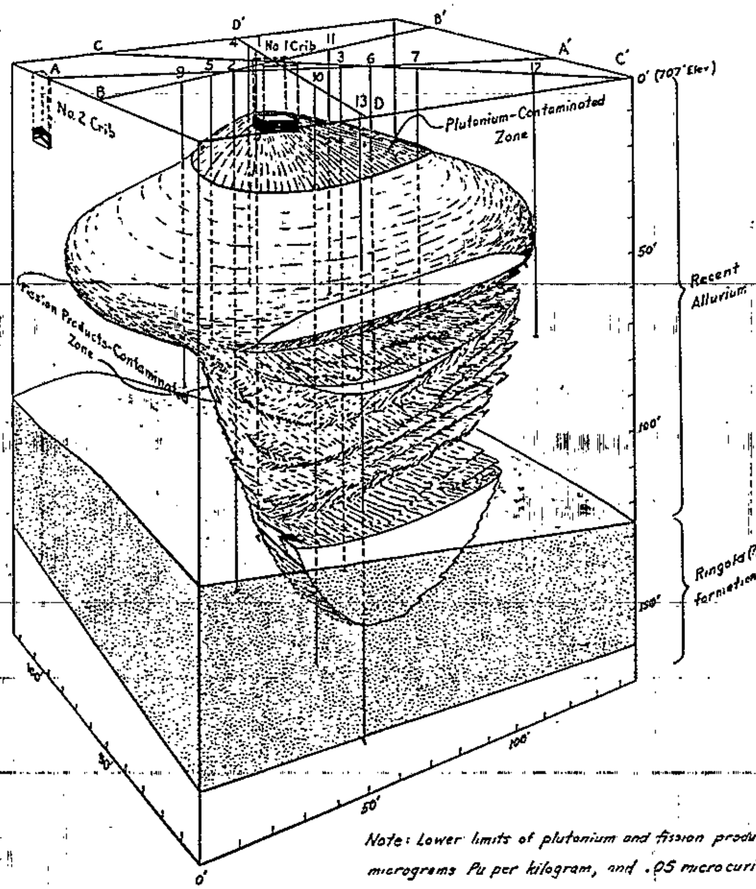
224-T BLDG. WASTE DISPOSAL

361-T TANK--CRIB AREA

Datum is mean sea level

By R.E. Brown
October 1947

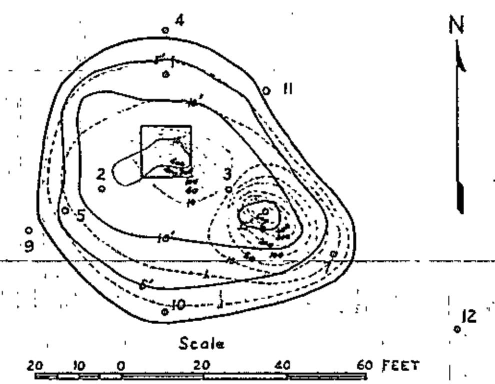
PERSPECTIVE BLOCK DIAGRAM



Note: Lower limits of plutonium and fission products chosen at .04 micrograms Pu per kilogram, and .05 microcuries fission product per kilogram respectively.

PLUTONIUM-CONTAMINATED ZONE

PLAN MAP



EXPLANATION

Contours denoting thickness of plutonium-contaminated zone

Contamination contours (*lines connecting points of equal intensity of contamination, measured in μg of Pu per kg*) location approximate

Contamination contours, location and intensity inferred

Test wells

In perspective block diagram:

Buff-colored sandy and silty clay bed. Top unit of the Ringold(?) formation

Test well

Test well in, or behind, contaminated zones.

B—B' Line of cross section

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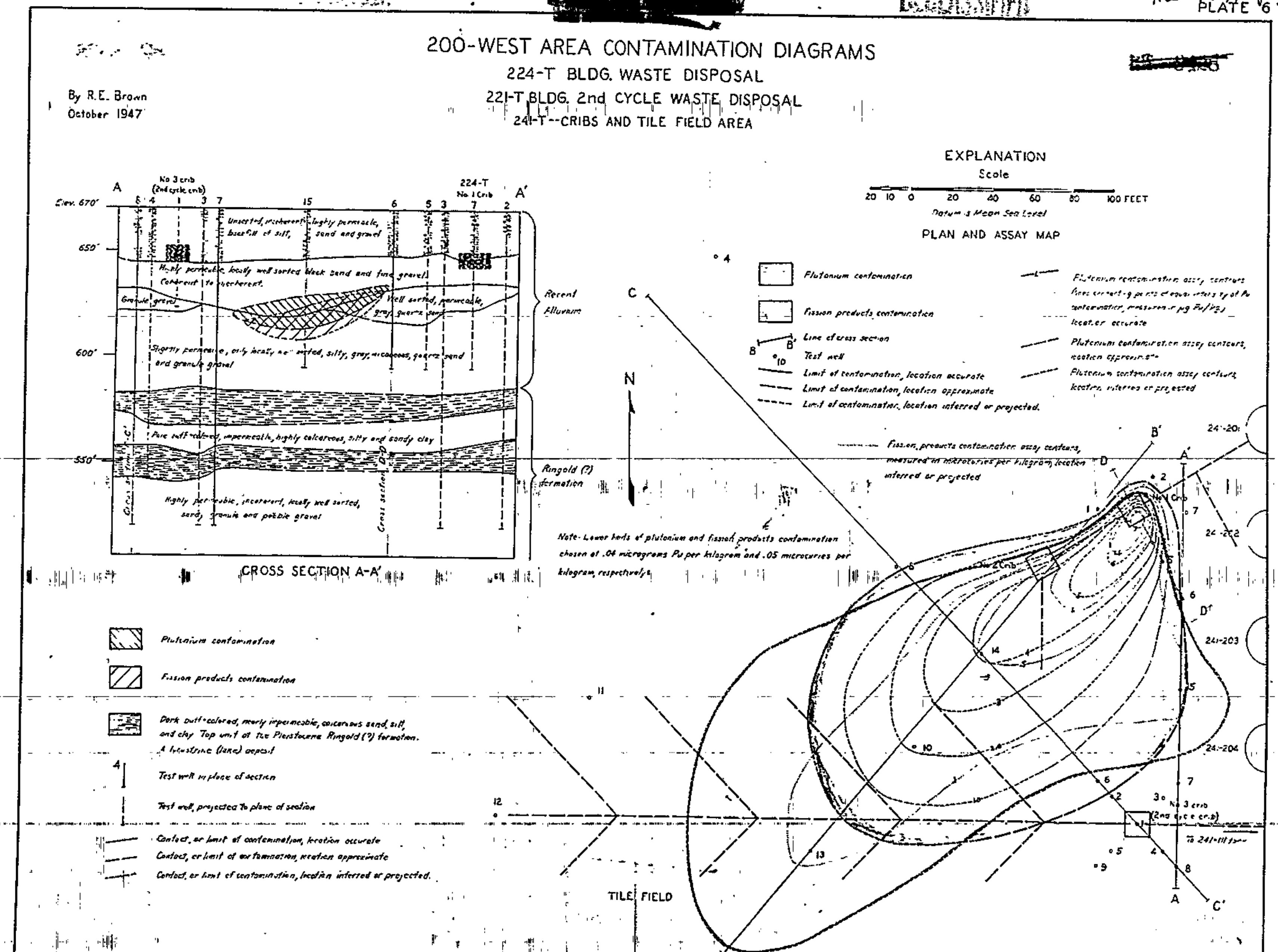

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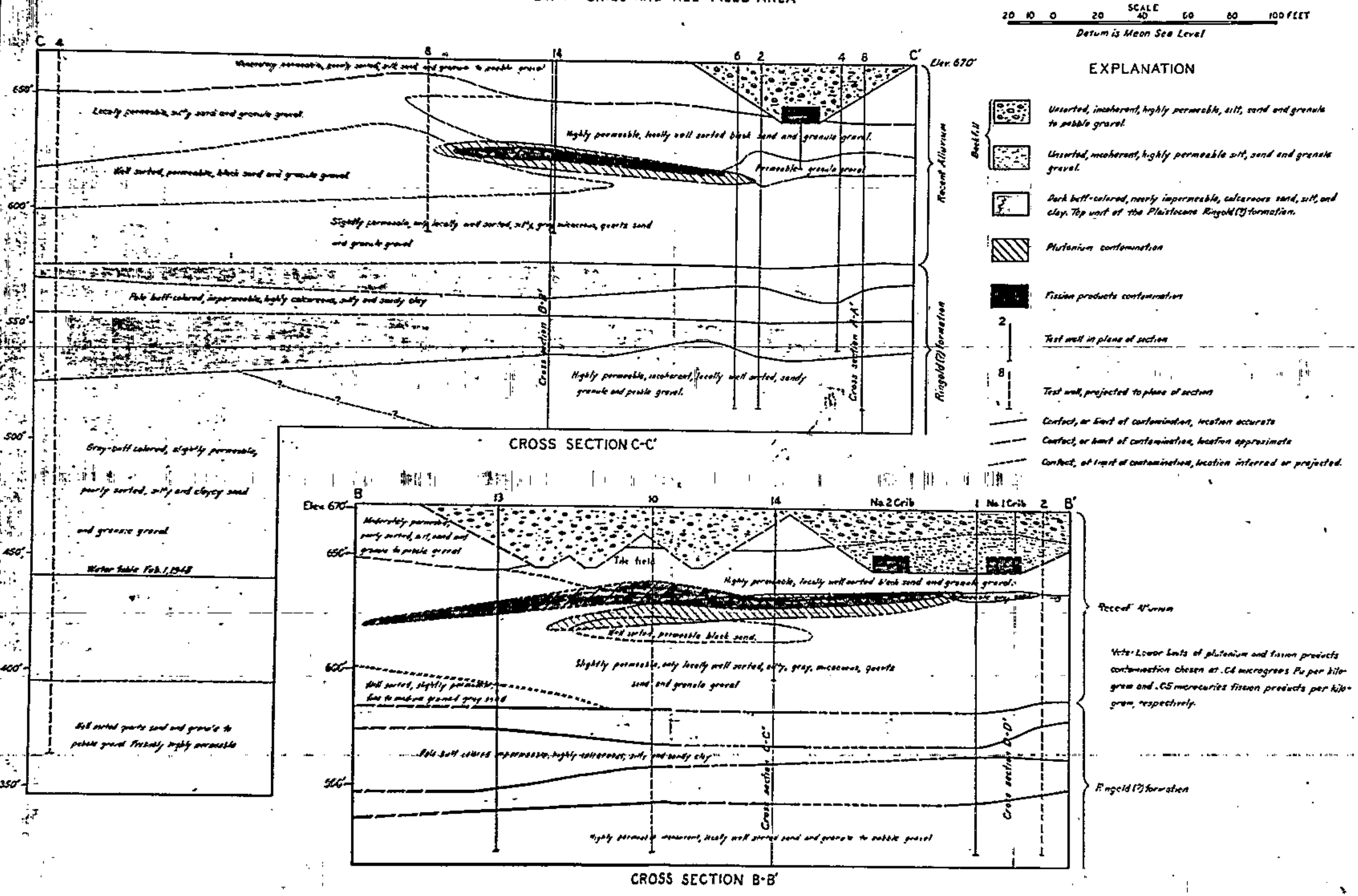
HW-9671 p.33
PLATE 7

~~HW-0488~~

200-WEST AREA CONTAMINATION DIAGRAMS
224-T BLDG. WASTE DISPOSAL
221-T BLDG. 2nd CYCLE WASTE DISPOSAL
241-T--CRIBS AND TILE FIELD AREA

By R.E. Brown
November 1947



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HW-9671 - p.34
PLATE 8

[redacted] [redacted] [redacted]

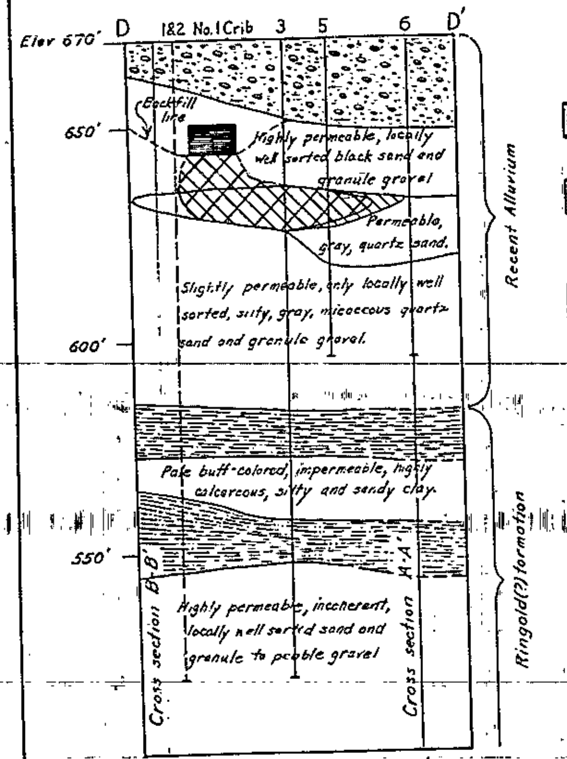
200-WEST AREA CONTAMINATION DIAGRAMS [redacted]

224-T BLDG. WASTE DISPOSAL

241-T-201 TANK--CRIB AREA

By R.E. Brown

November 1947



CROSS SECTION D-D'

Scale

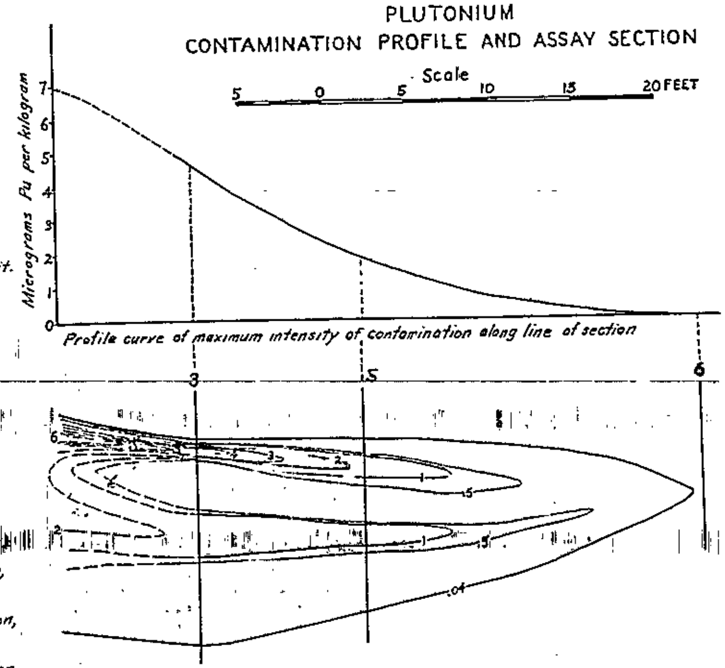
20 10 0 20 40 60 80 FEET

Datum is Mean Sea Level

EXPLANATION

- Unsorted, incoherent, highly permeable silt, sand and gravel. Largely backfill.
- Dark buff-colored, nearly impermeable, calcareous sand, silt and clay. Top unit of the Pleistocene Ringold (?) formation. A lake deposit.
- Plutonium contamination
- ~~Fission products contamination~~
- 3 Test well in plane of section
- 1 Testwell, projected to plane of section
- Contact, or limit of contamination, location accurate.
- Contact, or limit of contamination, location approximate.
- Contact, or limit of contamination, location inferred or projected.

PLUTONIUM
CONTAMINATION PROFILE AND ASSAY SECTION



Plutonium contamination assay contours (lines connecting points of equal intensity of contamination, measured in μg Pu/kg), location accurate.

Plutonium contamination assay contours, location inferred or projected.

Note: Lower limits of plutonium and fission products contamination chosen at .04 micrograms Pu per kilogram and .05 microcuries fission products per kilogram, respectively.

[redacted]